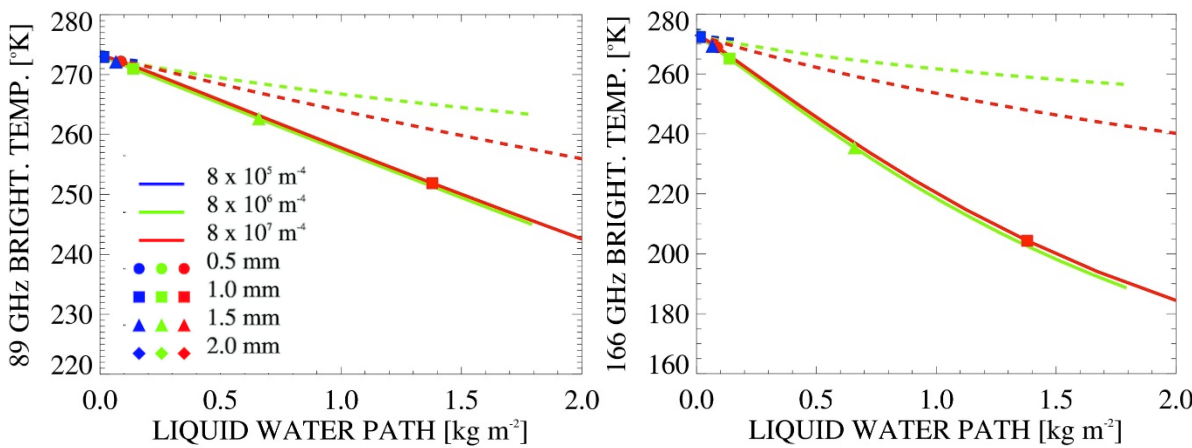
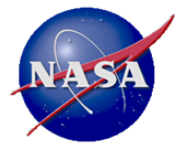


Remote sensing of snow using passive microwave sensors requires nonspherical particle models (above). Simulated microwave radiances at right show the impact of spherical (dashed) vs. nonspherical (solid) particle asymmetry of scattering.





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References:

Kwo-Sen Kuo, William S. Olson, Benjamin T. Johnson, Mircea Grecu, Lin Tian, Thomas L. Clune, Bruce H. van Aartsen, Andrew J. Heymsfield, Liang Liao, and Robert Meneghini, 2016: The Microwave Radiative Properties of Falling Snow Derived from Nonspherical Ice Particle Models. Part I: An Extensive Database of Simulated Pristine Crystals and Aggregate Particles, and Their Scattering Properties. *Journal of Applied Meteorology and Climatology*, **55**, 691-708.

Janko Gravner, and David Griffeath, 2009: Modeling of snow-crystal growth: A three-dimensional mesoscopic approach. *Physical Review E*, **79**, 011601.

Data Sources:

All figures are computer simulations from Kuo et al. (2016), with the exception of the top row of the top figure that is drawn from Gravner and Griffeath (2009), but which appears in Kuo et al. (2016).

Technical Description of Figures:

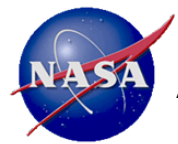
Top Figure, top row: from Gravner and Griffeath (2009), showing archetypal pristine ice crystals of different habits, ranging from dendritic forms, to a needle, to dendrites with broad branches, to a “sandwich” plate.

rows 2-4: aggregate snow particles created by collecting simulated pristine crystals, derived from the Gravner and Griffeath (2009) model, at different growth stages using a method described in Kuo et al. (2016). The succeeding rows show aggregates composed of ever-greater numbers of component crystals.

Bottom Figures: simulated microwave radiances at 89 GHz (left panel) and 166 GHz (right panel) upwelling from layers of snow particles with different column-integrated water paths. Line colors and symbols indicate different particle size distribution intercepts and median volume diameters, respectively. Solid lines are based upon nonspherical particle scattering properties, while dashed lines indicate a substitution of spherical particle asymmetry parameters for the nonspherical particle asymmetry parameters, to show the impact of asymmetry parameters on radiances. Clearly, the interpretation of precipitation water contents using the more realistic nonspherical snow particle models will lead to much different precipitation estimates relative to an interpretation using spherical particle models.

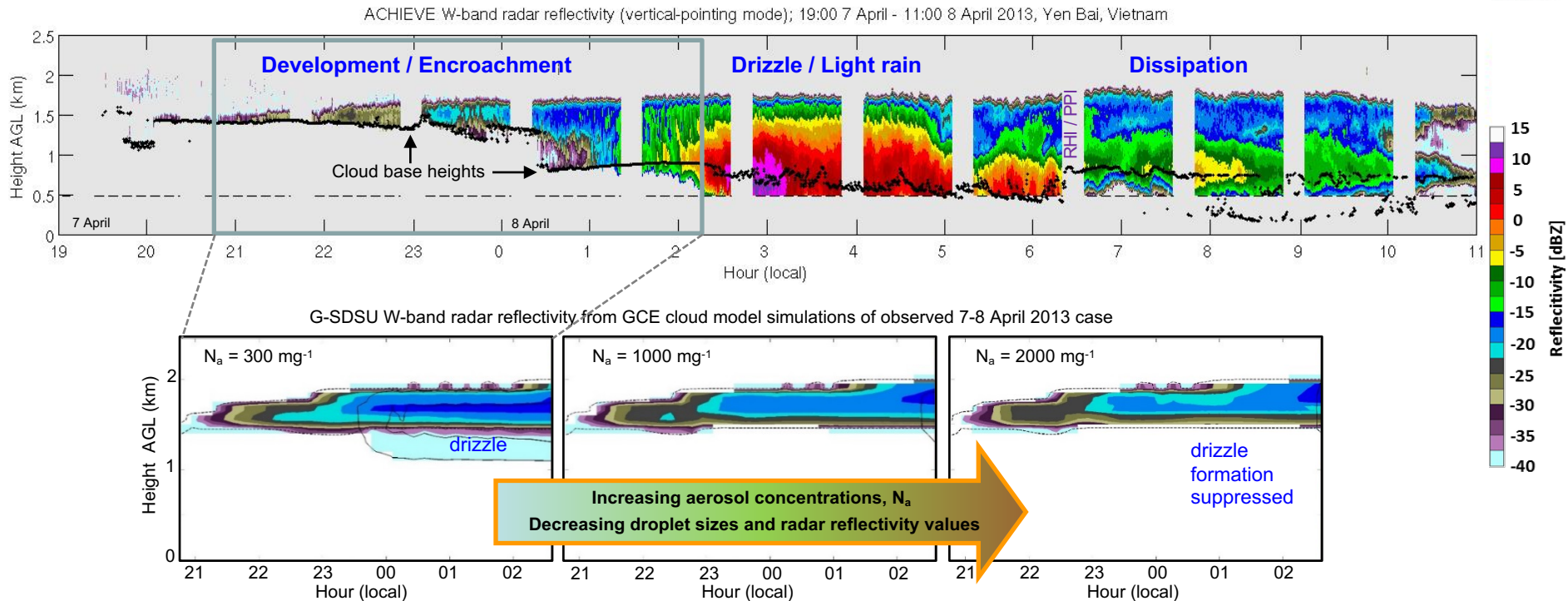
Scientific significance, societal relevance, and relationships to future missions:

At higher latitudes (greater than 40 °N or less than 40 ° S), snow contributes a significant proportion of the net precipitation at the earth’s surface, making it an important component of the global water cycle and a key climate indicator at those latitudes. The Global Precipitation Measurement mission core satellite observatory is fitted with a downward-looking weather radar and passive microwave radiometer. These multichannel instruments are designed to work synergistically to estimate surface precipitation and precipitation vertical structure over the 65 °S to 65 °N latitude range. Snow affects both spaceborne radar and microwave radiometer observations— it reflects radar pulses, and the observed difference between radar reflectivity observations at the two GPM radar frequencies indicates the median size of the snow particles; snow primarily scatters microwave radiances upwelling from the earth’s surface or underlying rain layers, diluting those radiances with low-intensity backscatter from the cosmic background. Kuo et al. (2016) and other recent studies have begun to quantify the impact of snow particle shape on both radar reflectivities and the scattering of microwave radiances. Snow particles generally have irregular, nonspherical shapes, and these are simulated by Kuo et al. (2016), and their radiative properties are computed. Although the nonsphericity of snow particles has an influence on radar reflectivities at the GPM channel frequencies, it has the greatest impact on higher-frequency microwave radiances sensed by the GPM radiometer, such as those at 89 GHz and 166 GHz. This impact on microwave radiances is mainly due to the lesser forward scattering by nonspherical particles relative to spheres of the same mass, leading to lower upwelling radiances at the higher frequencies. The proper interpretation of the higher-frequency microwave channel data from GPM, as well as other microwave sensors such as SSMIS and AMSR2, therefore depends on models of the atmosphere containing nonspherical snow particles. Proposed satellite missions such as ACE and CaPPM will utilize higher-frequency radar and passive microwave channels to interpret cloud and precipitation distributions, and so further research into the structural and radiative properties of snow particles will be needed to better quantify their impact on remote-sensing observations.



Advancements in Observing and Modeling Coupled Aerosol-Cloud Systems

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An inaugural deployment of NASA-GSFC's SMARTLabs-ACHIEVE mobile laboratory monitored for the *first time ever* with a ground-based cloud radar the evolution of pre-monsoon continental stratocumulus in the presence of biomass-burning aerosols. Such detailed observations are critical for improving models simulating aerosol-cloud-precipitation processes and for validating future spaceborne cloud measurements.



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References:

Loftus, A. M., S.-C. Tsay, P. Pantina, C. Nguyen, P. M. Gabriel, X. A. Nguyen, A. M. Sayer, W.-K. Tao, and T. Matsui, 2016: Coupled aerosol-cloud systems over northern Vietnam during 7-SEAS/BASELInE: A radar and modeling perspective. *Aerosol and Air Quality Research*, doi:10.4209/aaqr.2015.11.0631.

Lin, N.-H., A. M. Sayer, S.-H. Wang, A. M. Loftus, T.-C. Hsiao, G.-R. Sheu, N. C. Hsu, S.-C. Tsay, and S. Chantara, 2014: Interactions between biomass-burning aerosols and clouds over Southeast Asia: Current status, challenges, and perspectives. *Environmental Pollution*, 195, 292-307, doi:10.1016/j.envpol.2014.06.036.

Data Sources: Surface-based Mobile Atmospheric Research and Testbed Laboratories (SMARTLabs) Aerosol, Cloud, Humidity Interactions Exploring and Validation Enterprise (ACHIEVE) and Chemical, Optical, and Microphysical Measurements of In-situ Troposphere (COMMIT) mobile laboratories; CLOUDSat; CALIPSO; AERONET; Goddard Cumulus Ensemble (GCE) cloud model; Goddard-Satellite Data Simulator Unit (G-SDSU). SMARTLabs is supported by NASA Radiation Sciences Program managed by Dr. Hal B. Maring. Partial support provided by the NASA Postdoctoral Program and NASA grant NNX14AL96G under the NASA New Investigator Program managed by Dr. Ming-Ying Wei.

Technical Description of Figure: (Top panel) Time series of radar reflectivity from ACHIEVE's W-band (94 GHz or 3.2 mm) dual polarization pulsed-Doppler radar, and 910 nm ceilometer-derived cloud base heights (black dots), showing in unprecedented detail the nighttime development/encroachment of a stratocumulus (Sc) deck and evolution into a lightly precipitating system (after ~02:00 local time) on 7-8 April 2013 over Yen Bai, Vietnam during the Seven Southeast Asian Studies/Biomass-burning Aerosols & Stratocumulus Environment: Lifecycles & Interactions Experiment (7-SEAS/BASELInE) campaign. Breaks in reflectivity time series coincide with radar scans in Range Height Indicator (RHI) and Plan Position Indicator (PPI) modes. (Bottom panels) Time-height plots of G-SDSU simulated ground-based W-band radar reflectivity from idealized GCE simulations of the developmental phase of this Sc cloud case show that as aerosol concentration increases, radar reflectivity of the simulated cloud deck decreases primarily due to decreases in cloud droplet sizes (not shown). The simulation also reveals suppressed drizzle development (solid black contours in bottom panels) with increased aerosol loading. Due to sparse atmospheric soundings in this region, model simulations were initialized using only the 19:00 7 April sounding from Hanoi, Vietnam (~120 km east of Yen Bai), and therefore do not capture the development of the lower secondary cloud deck after 00:30 and light precipitation after 02:30 seen in the observations. Because the model is highly sensitive to the atmospheric state variables, future endeavors should better constrain the model with either direct measurements from collocated instruments (e.g., balloon or UAV soundings) or retrievals (Atmospheric Emitted Radiance Interferometer)

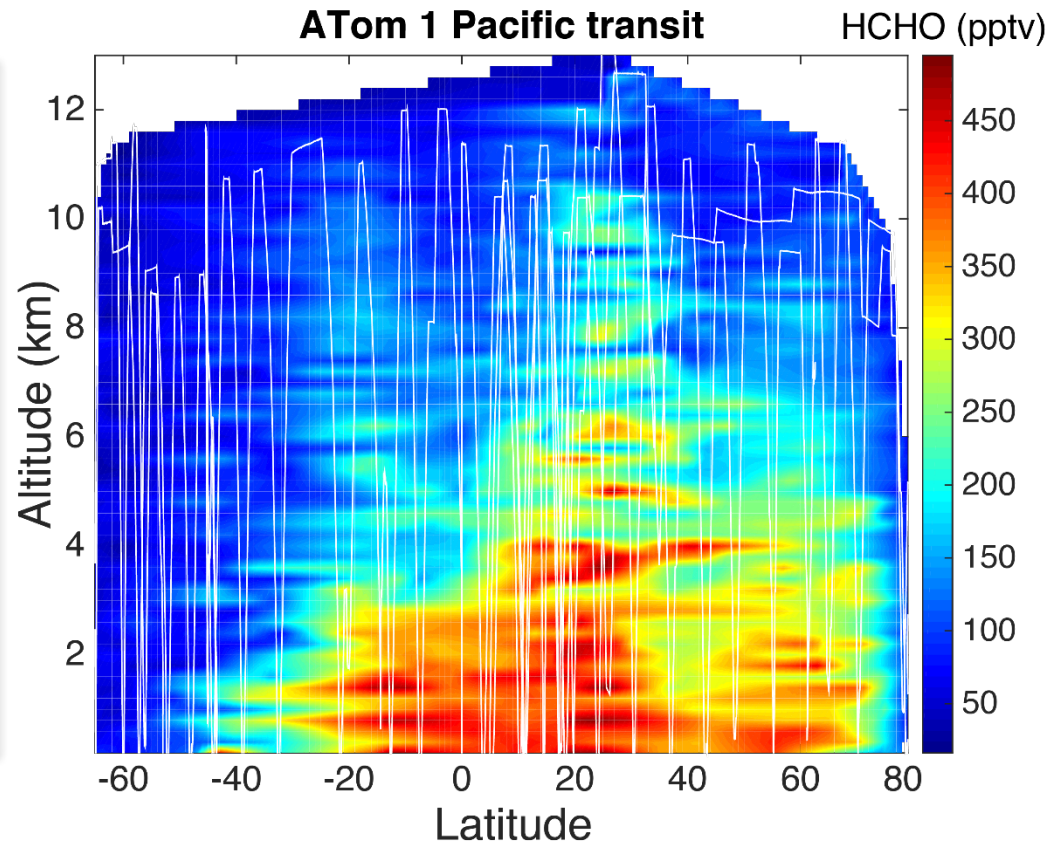
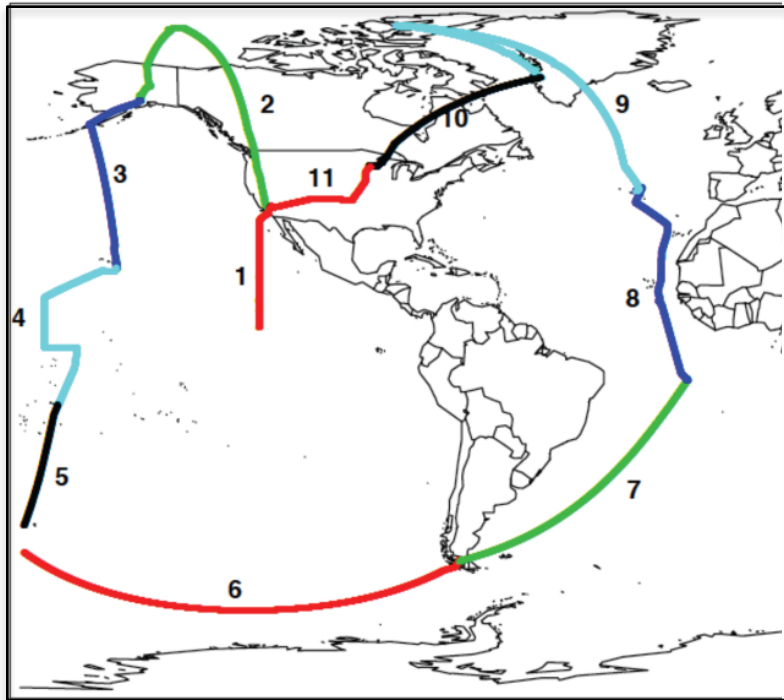
Scientific significance, societal relevance, and relationships to future missions: Ground-based cloud radar measurements, though spatially limited, provide detailed information on low-level Sc cloud properties currently not attainable from much coarser resolution spaceborne radar systems which also suffer from surface clutter and signal attenuation. Such data can be used to both constrain and evaluate models that simulate the potential impacts of these coupled aerosol-cloud systems on local and regional weather and air quality. Because microphysical processes and cloud radiative properties depend on the cloud/rain drop size distribution (CDSD), its accurate prediction is critical. The modeling portion of this study employs a new triple-moment (3M) bulk microphysics scheme for fully prognostic CDSDs as an efficient alternative to computationally expensive size-resolving (bin) microphysics schemes. Deployable ground-based cloud radar provide critical measurements of cloud properties in regions with strong aerosol-cloud interaction signals and aid the design of future spaceborne cloud measurements (e.g., a NASA ACE-like mission). Systematic model simulations, utilizing the GCE with 3M microphysics, and a larger-scale regional model (e.g., NU-WRF) equipped with a detailed aerosol module, bridge the gap between in-situ and remote measurements at field campaigns and collocated satellite measurements for understanding the physical processes involved in aerosol-cloud interactions.



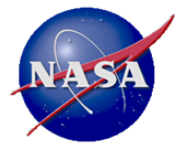
Atom provides a new perspective on tropospheric formaldehyde

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(Left) The Atmospheric Tomography Mission (ATom) sampled the abundance of trace gases in the atmosphere over the Earth's remote oceans. (Right) Measurements of formaldehyde (HCHO) reveal a distinct pattern that provides new insights to the chemistry of the remote troposphere.



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Data Sources: Data are provided by the NASA GSFC In Situ Airborne Formaldehyde Instrument (ISAF) obtained during the Atmospheric Tomography (ATom) campaign. ATom is an Earth Venture suborbital campaign that is designed to quantify the chemical processes that control the short-lived climate forcing agents CH_4 , O_3 , and black carbon in the Earth's atmosphere. Many of these processes are controlled by trace species that cannot be measured from space and require highly sensitive airborne instruments for accurate measurements. During ATom, *In situ* measurements of multiple reactive and non-reactive species are used to determine how the chemical reactivity of the atmosphere is affected by anthropogenic emissions on a global scale. The participants and instrumentation are described at the ATom website: <https://espo.nasa.gov/home/atom>.

Technical Description of Figures:

Figure 1: The map on the left shows the flight paths of the NASA DC-8 during ATom-1 between August 1 and August 23, 2016. Each of these flights consisted of multiple vertical profiles that sampled the atmosphere at altitudes between 150 m and 12000 m. The flights were designed to provide a representative slice of the atmosphere during the northern hemisphere (NH) summer. Measurements over the mid-oceans minimize the sampling of localized emission sources and simplify the comparison with global models that rely on generalized emissions inventories. Future ATom campaigns will provide observations during the NH winter, fall, and spring.

Figure 2: The figure on the right shows the concentration of HCHO measured *in situ* with the ISAF instrument plotted versus latitude and altitude. The thin white lines show the trajectory of the DC-8 and the location of the measurements. The measurements were obtained in the flight legs labelled 1 – 6 in the map shown on the left. The HCHO data are interpolated on a rectangular grid using a linear function. Data obtained over land near the airports used for the deployments are excluded.

Scientific significance, societal relevance, and relationships to future missions: The formaldehyde observations from Atom cover an unprecedented range of altitudes and latitudes over the remote oceans. The distribution of formaldehyde shown in the Figure 2 shows how sources of formaldehyde – biogenic volatile organic compounds (VOCs) are distributed between the poles. The surprisingly high abundance of formaldehyde in even the most remote locations indicates relatively large sources of VOCs in these regions. These sources result in enhancements of formaldehyde which in turn produces OH, the primary tropospheric sink of methane. Measurements like these provide an important source for constraining the chemistry-climate models that are used to predict the climate impact of CH_4 and O_3 .